

Progress on Laser Assisted Discharge Produced Plasma (LDP) EUV Light Source Technology

Rolf Apetz

2012 International Symposium on EUV
Lithography

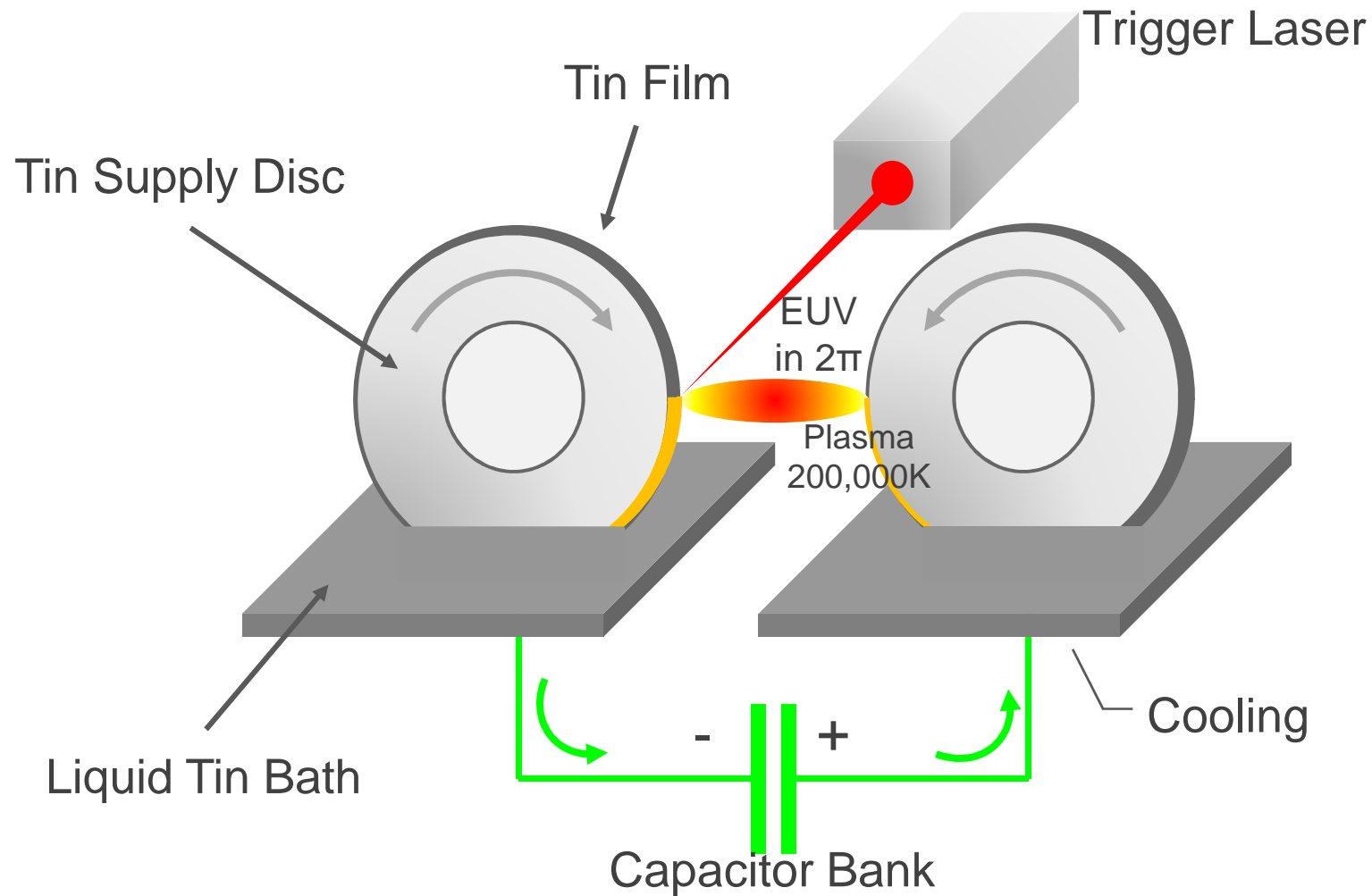
Brussels, October 2012



USHIO
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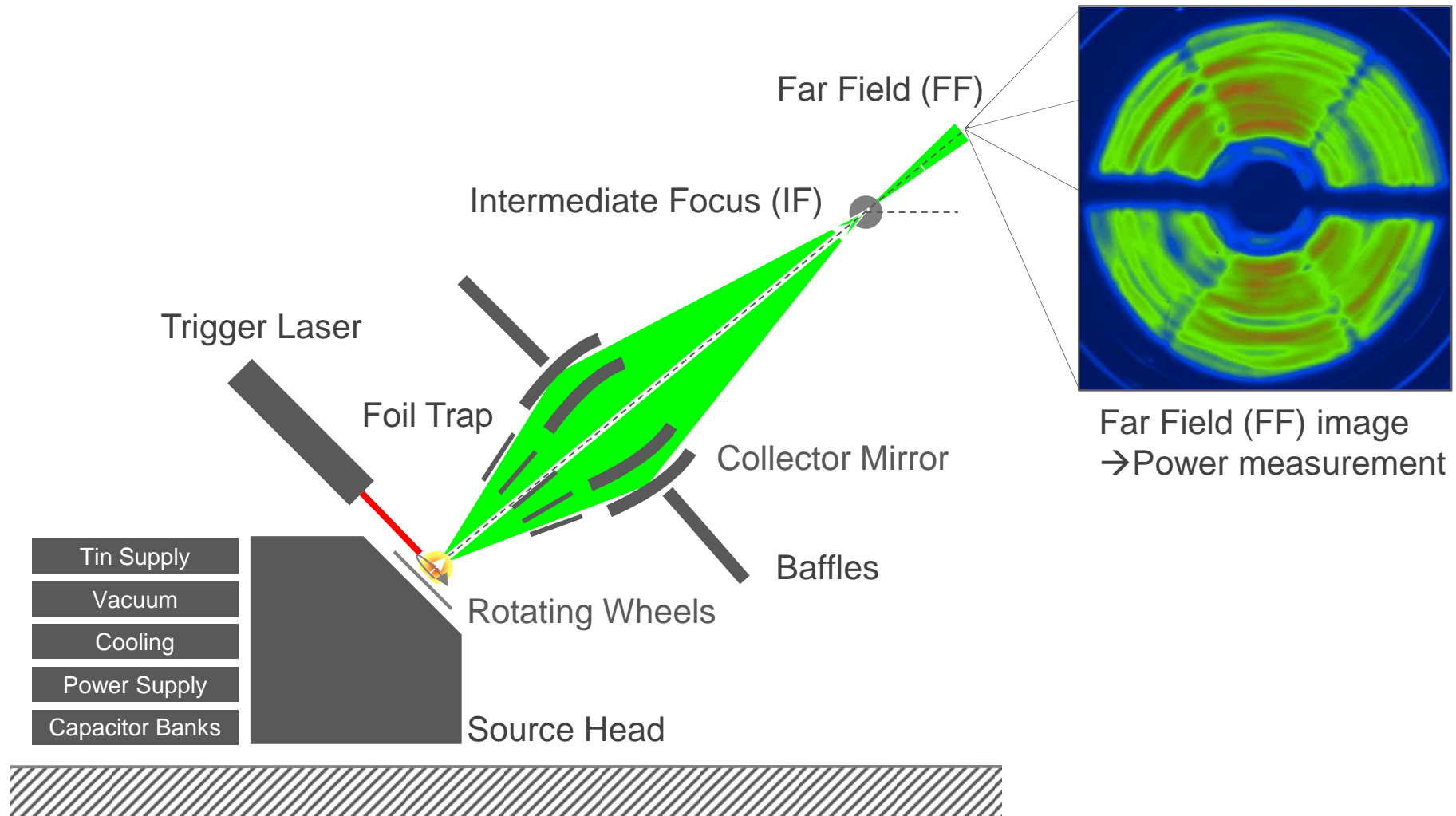
XTREME's LDP* Concepts – A Quick Refresher

*Laser assisted Discharge Plasma



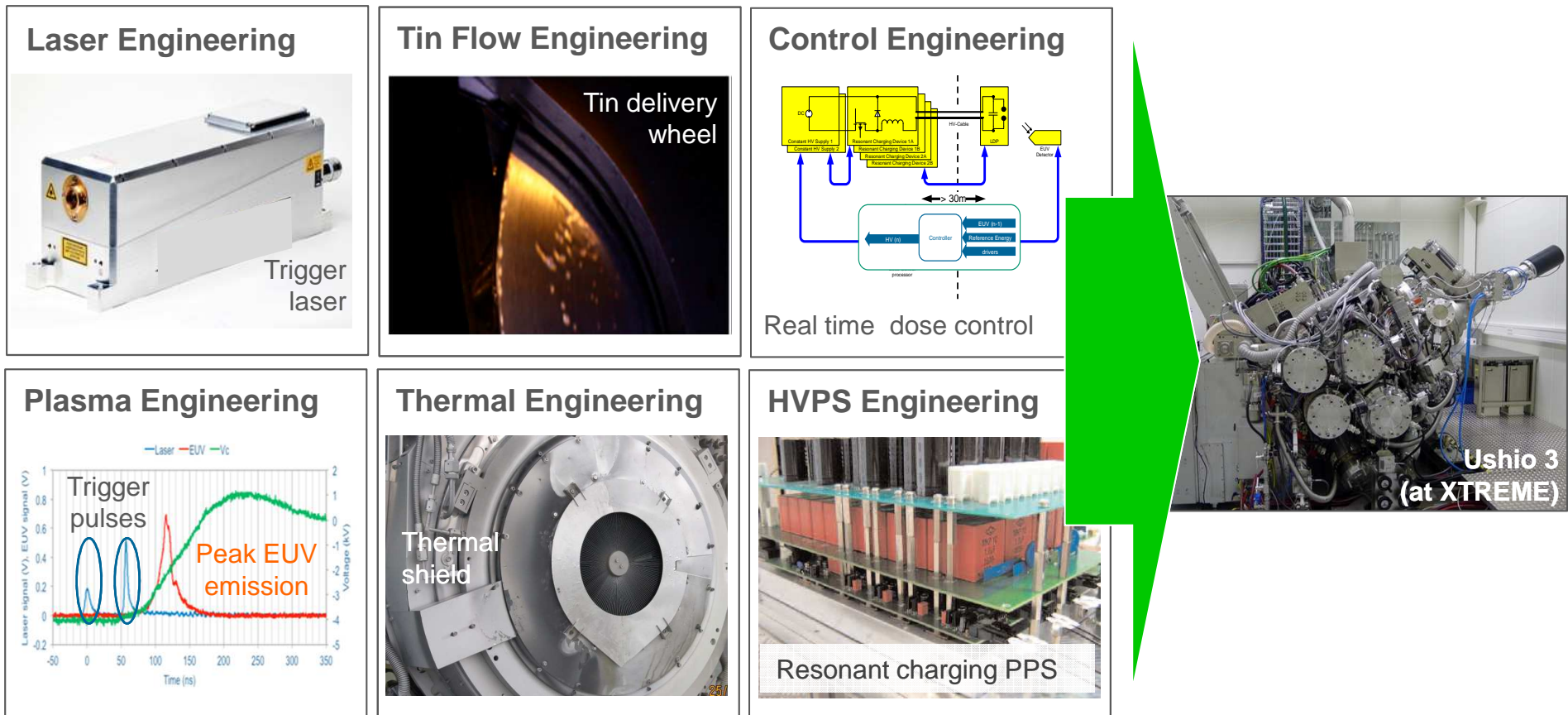
XTREME's LDP* Concepts – A Quick Refresher

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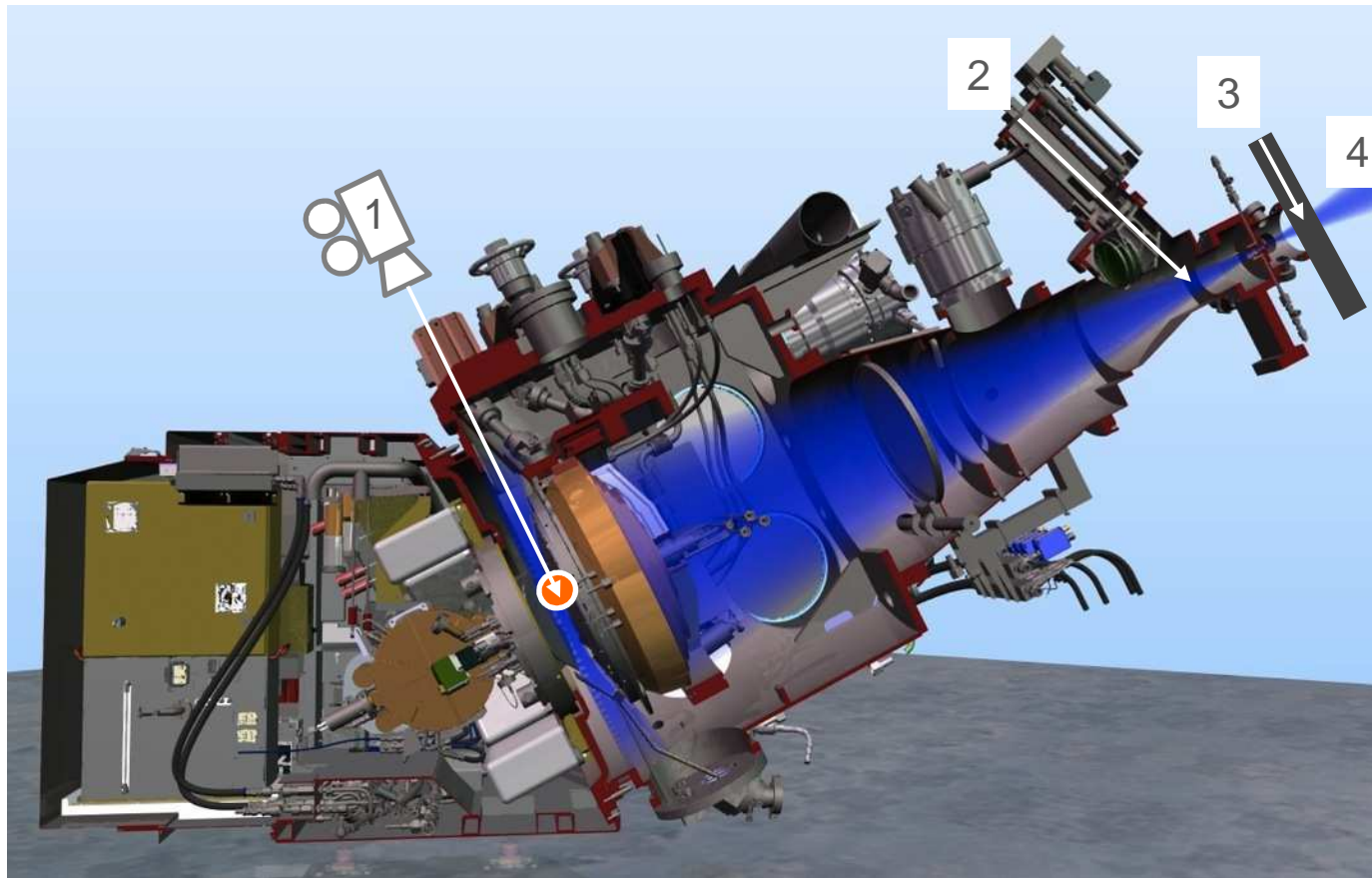


Could Physics Be Integrated Into A **Viable Technology** ?

- Last July, XTREME has resumed power scaling experiments on Ushio 3 integrated system to investigate short term scalability



Measuring Collectable EUV Power



1 - At plasma

Collectable in-band power with pinch camera and calibrated energy monitor

2 - Before IF

NFST camera can be moved in the EUV beam

3 - Behind IF

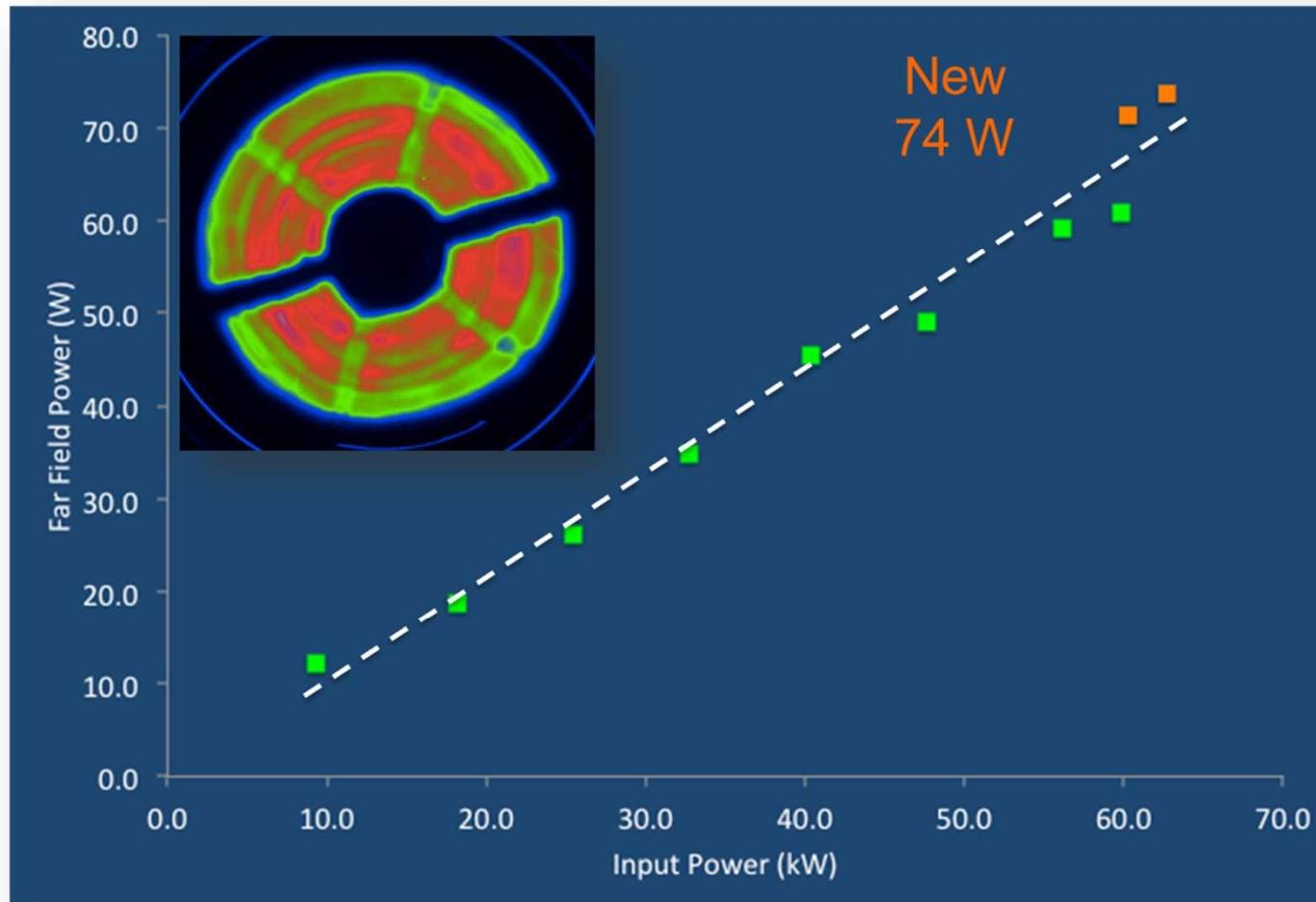
FFST (external sensor – XTREME only)

4 – Inside scanner

Energy Sensor at reticle level

Just In:

New Record 74 W After IF



Burst mode
200 ms / 12% DC

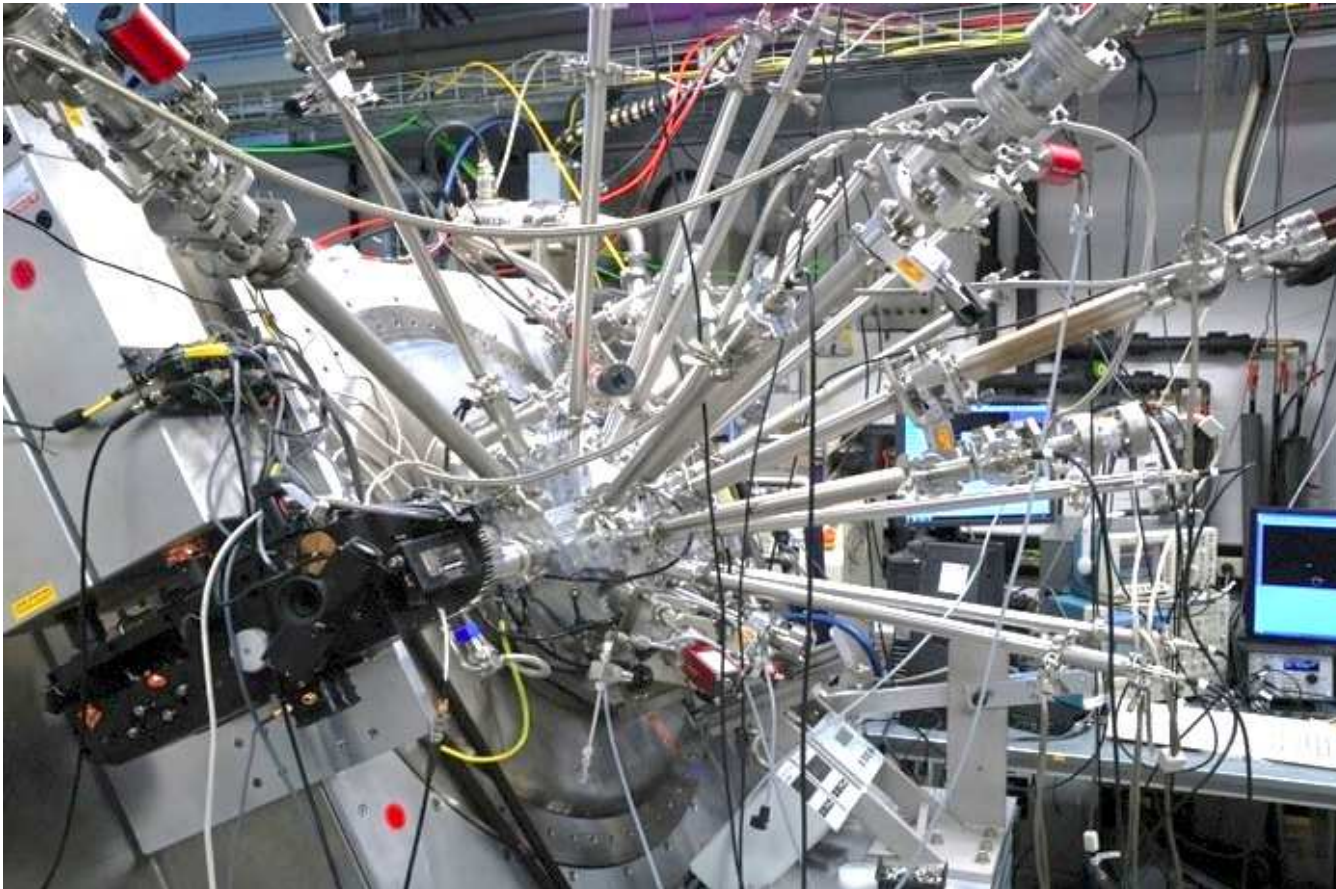
Pulse energy
3-4 J

1 hour run at 74W

Could LDP Scale Beyond 250 W ?

- Why would anyone pursue a given technological path if it does not scale in the long term ?

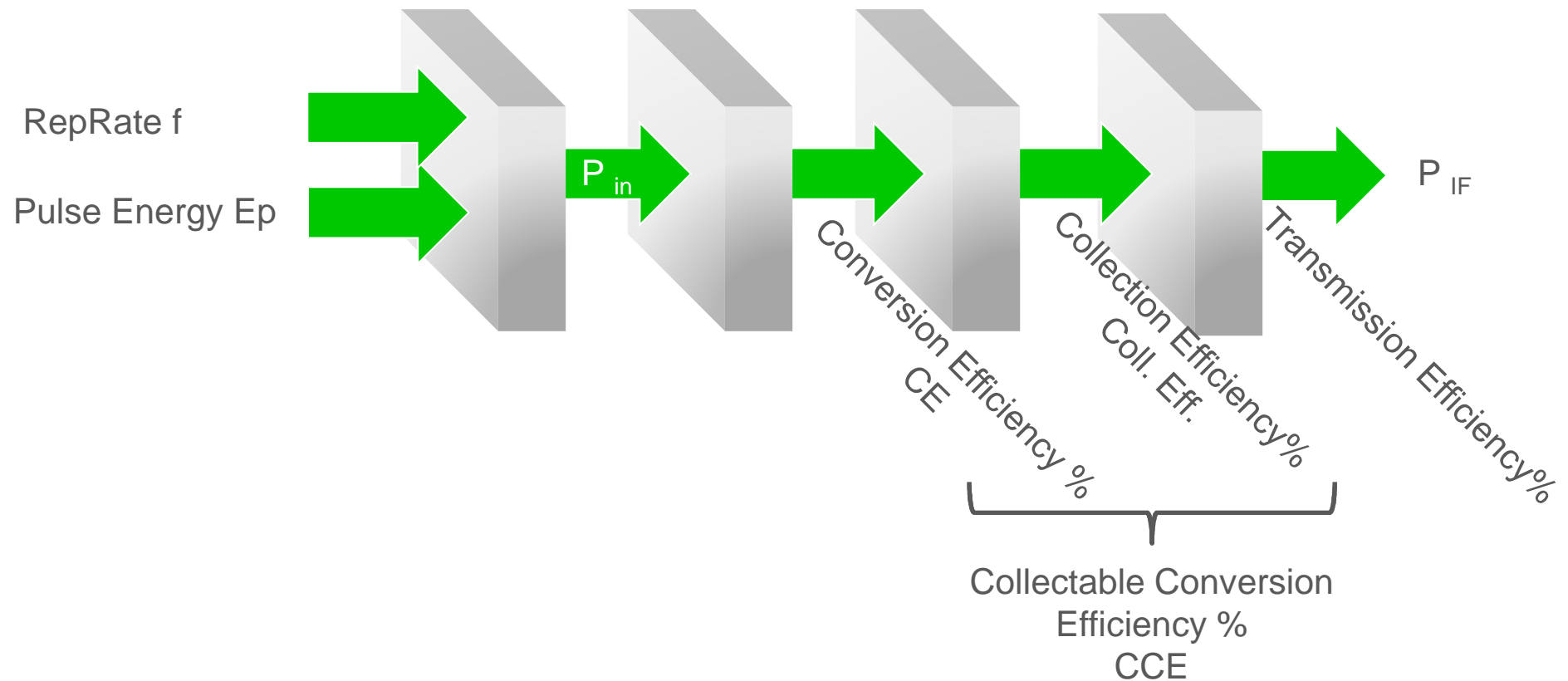
→ A test stand (Obelix II) has been specially built to allow XTREME to validate LDP long term scalability



Power scalability:

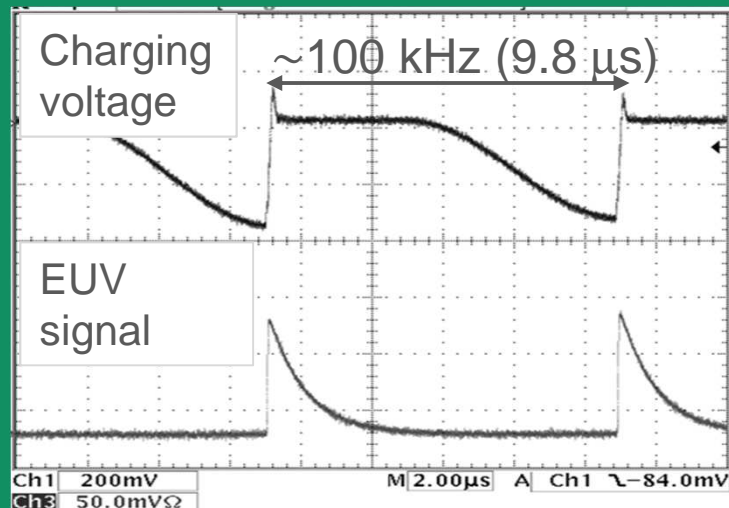
- Reprate scalability
- Pulse energy scalability
- Conversion efficiency optimization
- Collection efficiency optimization

First, What It Means To Scale LDP



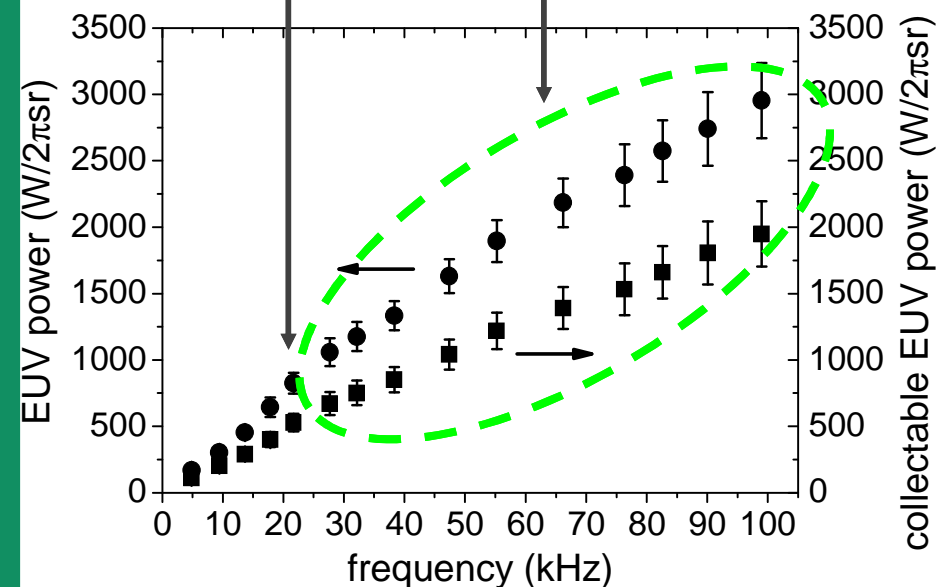
LDP RepRate Scalability

- LDP's replate long term scalability is proven **BEYOND the requirements for 3300B (250W)**
 - Interlaced low energy pulses experiments



Beyond NXE:3300B

NXE:3300B
equivalent Repate

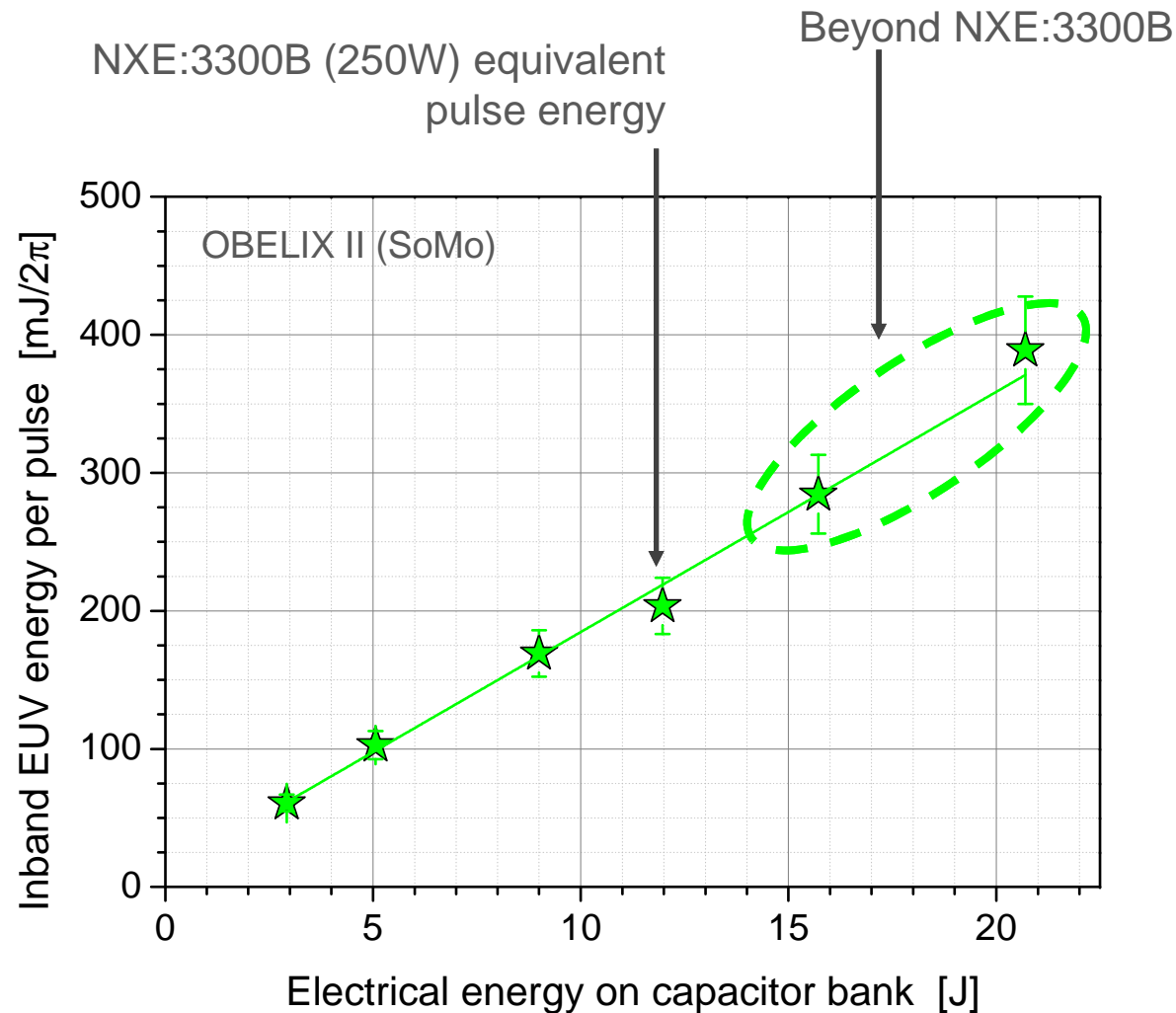


Experiment

Frequency = $1/(\Delta T \text{ between pulse 1 and 2})$

LDP Pulse Energy Scalability

- LDP's long term pulse energy scalability is proven **BEYOND** the requirements for NXE:3300B (250W)

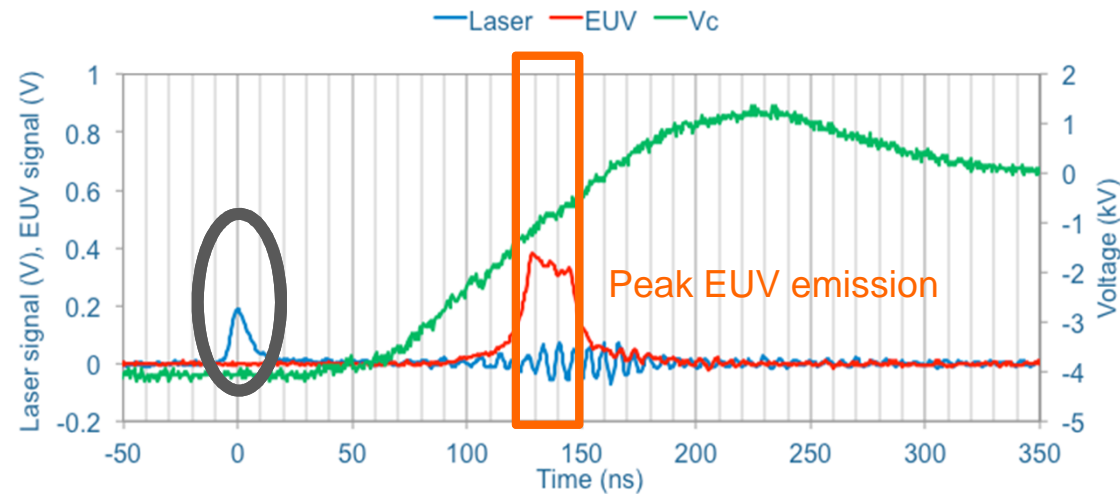


Please see also
Poster P-SO-05
Felix Kuepper,
Fraunhofer ILT

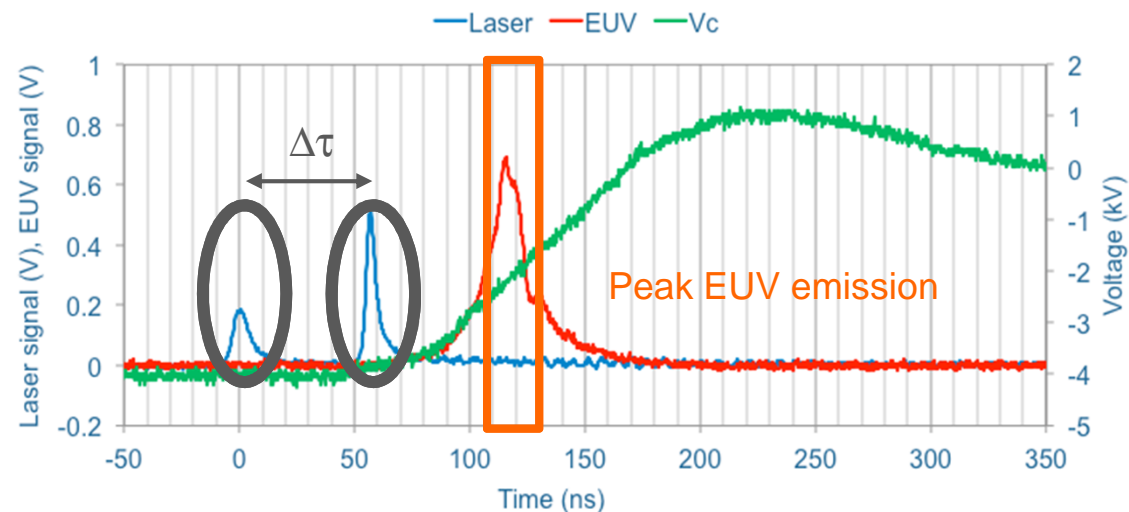
Plasma Engineering

- Tailoring the laser pulse train allows XTREME to engineer the plasma emission

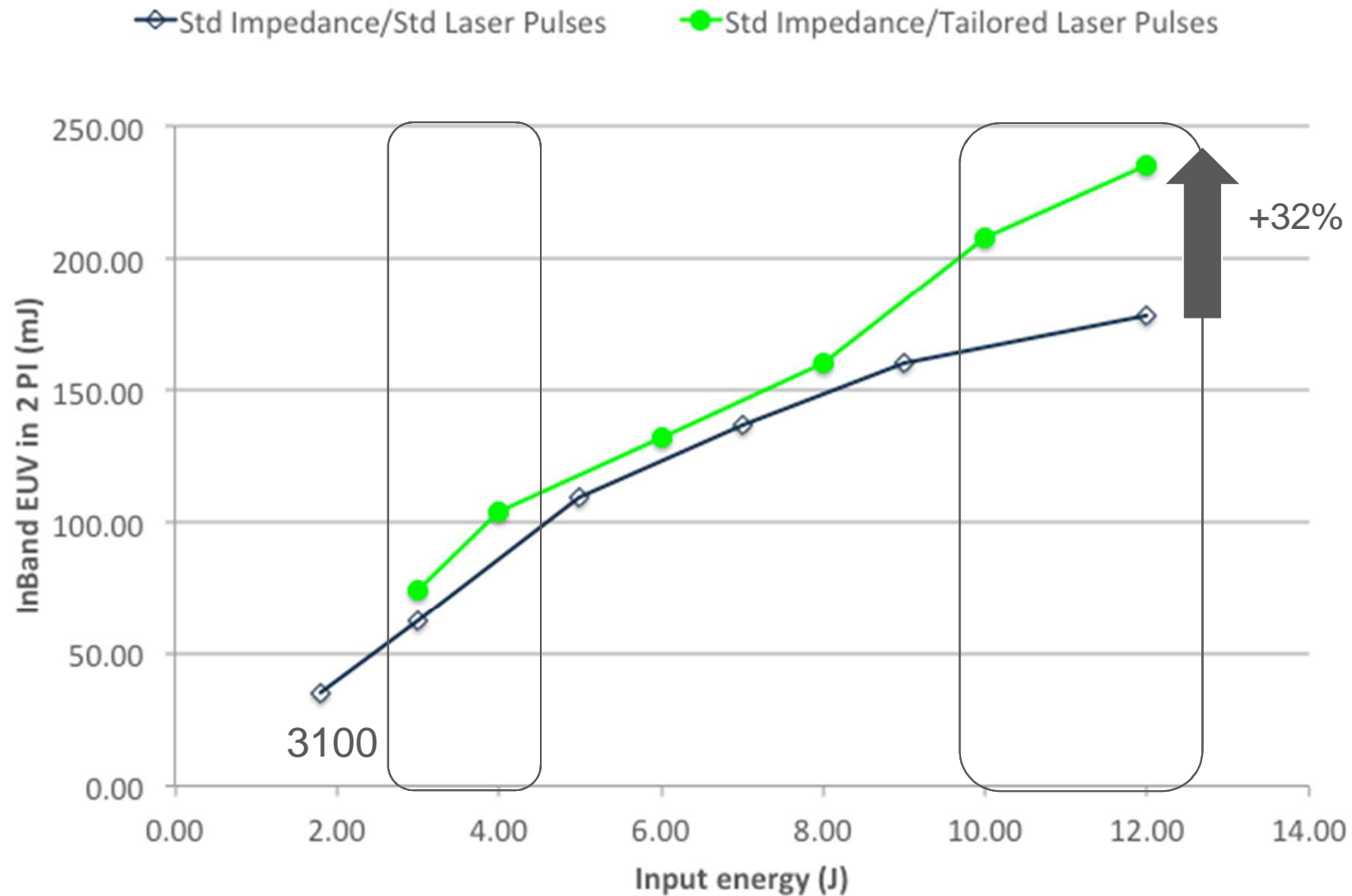
Single trigger laser pulse



Double trigger laser pulse

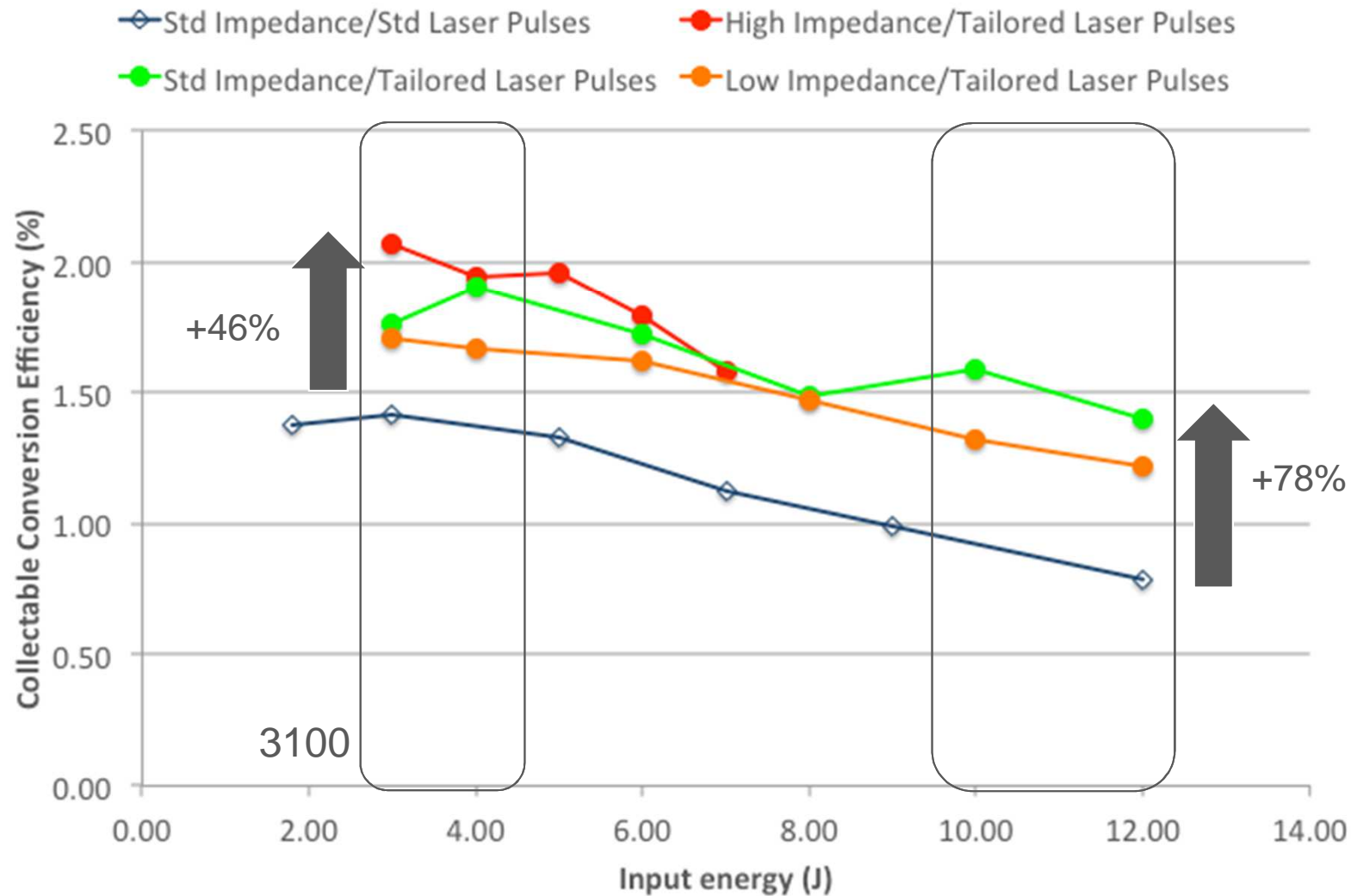


Engineering **Pulse Energy** With Lasers



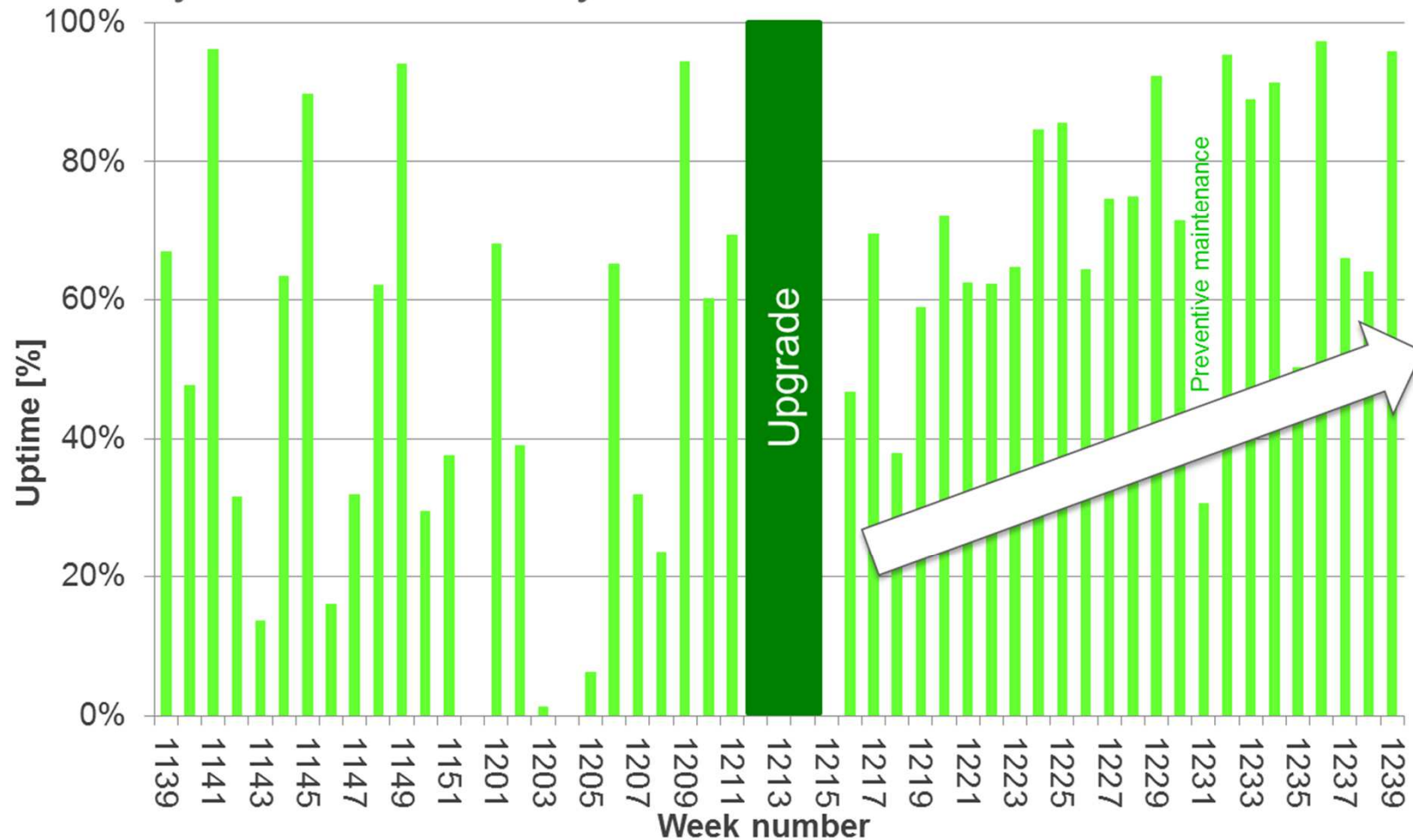
Engineering Collectable Conversion Efficiency

- CCE (Collect. Conv. Eff.) = Conversion Efficiency x Collection Efficiency



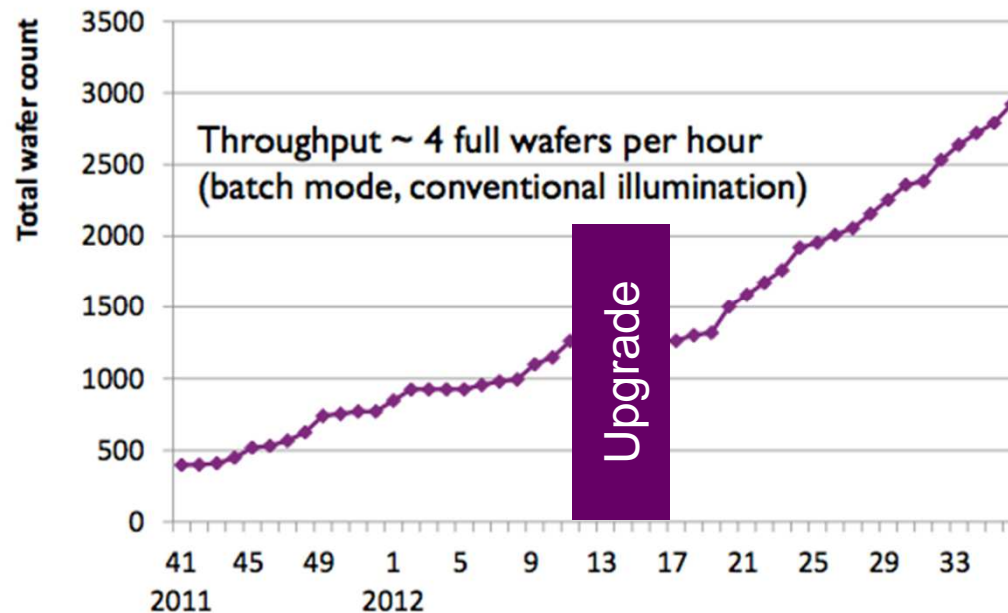
After Upgrade, Ushio 1 Uptime Has Steadily Increased ...

- Recently, uptime exceeds 90% (13 wk average now exceeds 75%)
- Volatility has also drastically decreased



... And **Utilization (7x24) Is High**

TOTAL NUMBER OF EXPOSED WAFERS NXE:3100 CUMULATIVE WAFERCOUNT

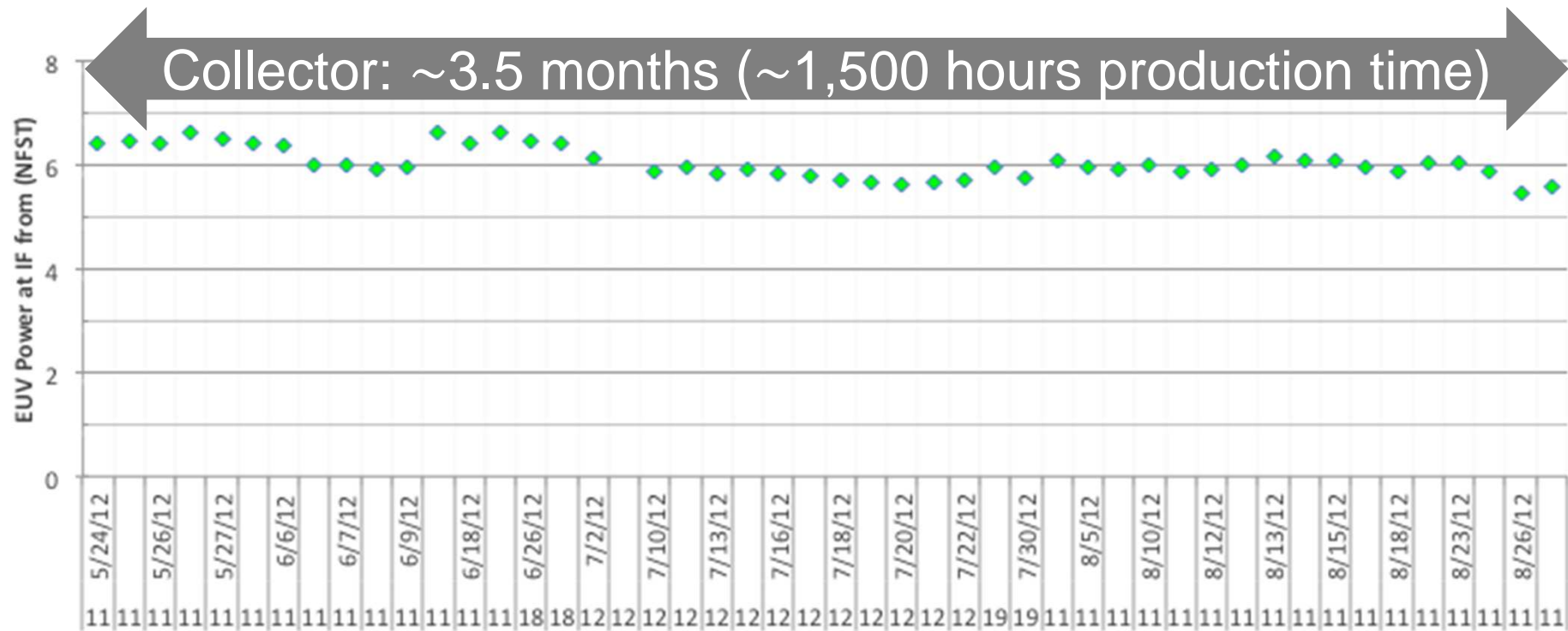


Cumulative wafercount now 3000 exposed wafers
since tool installation – clear productivity increase since May 2012

3,000 wafers have
been printed so far

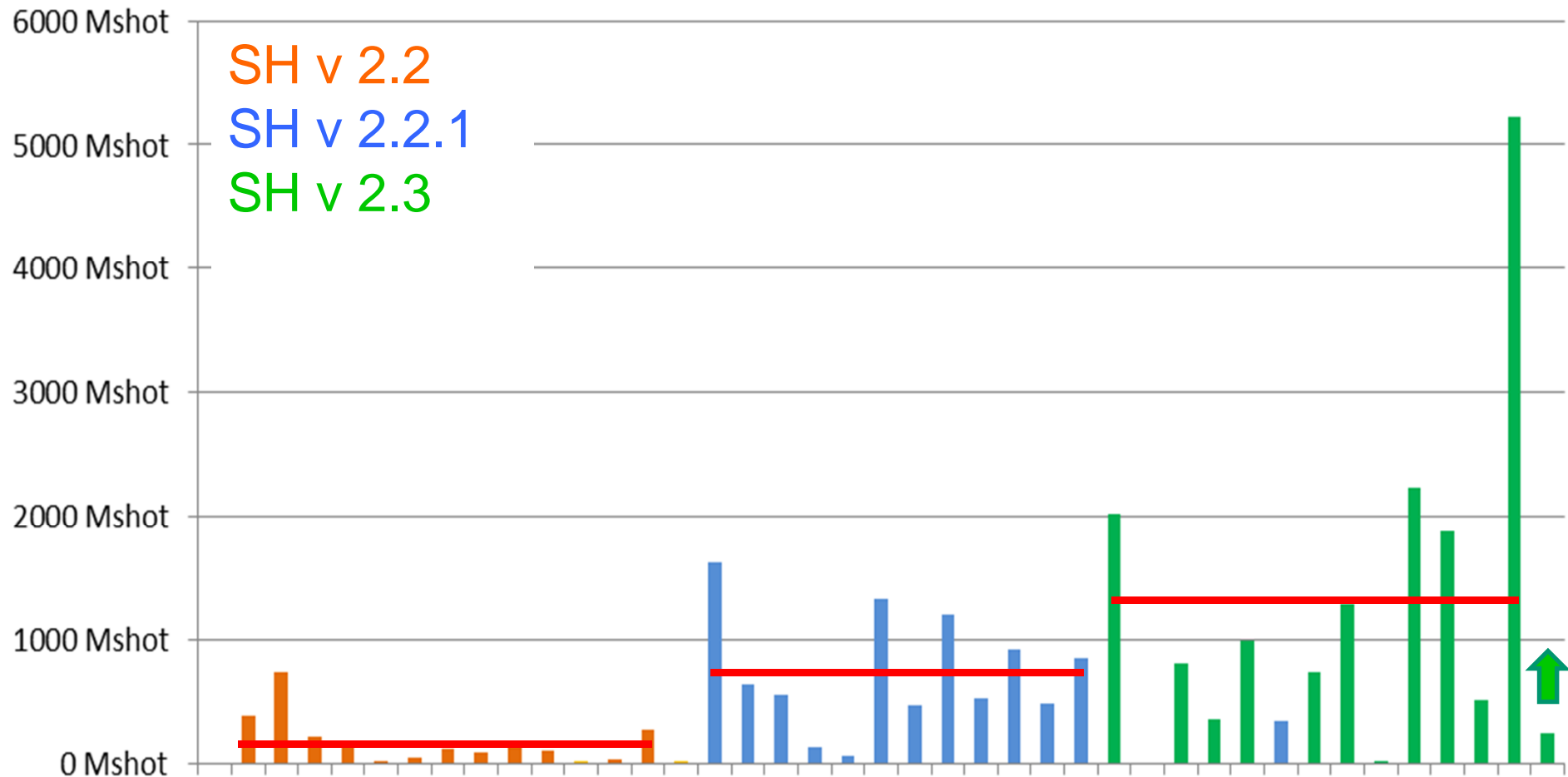
Long Collector Lifetime Is Achieved

- Power at IF is stable over the collector life



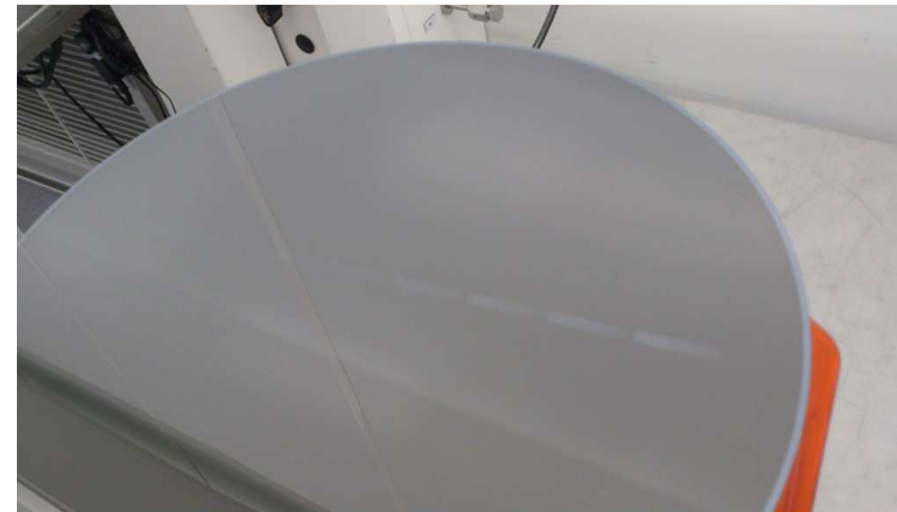
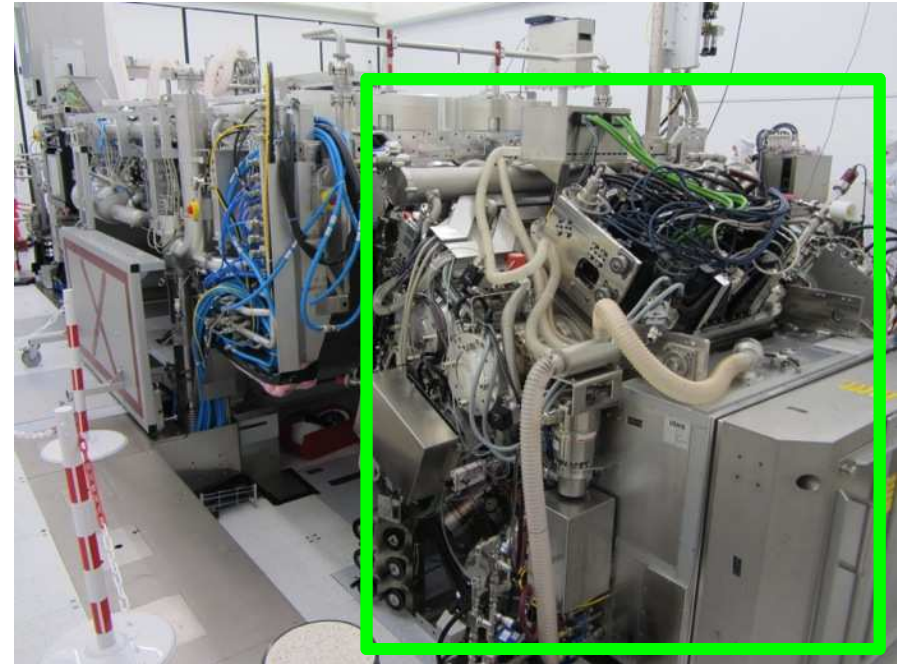
Lifetimes Have Increased

- Source Heads (SH) are no more the primary source of downtime



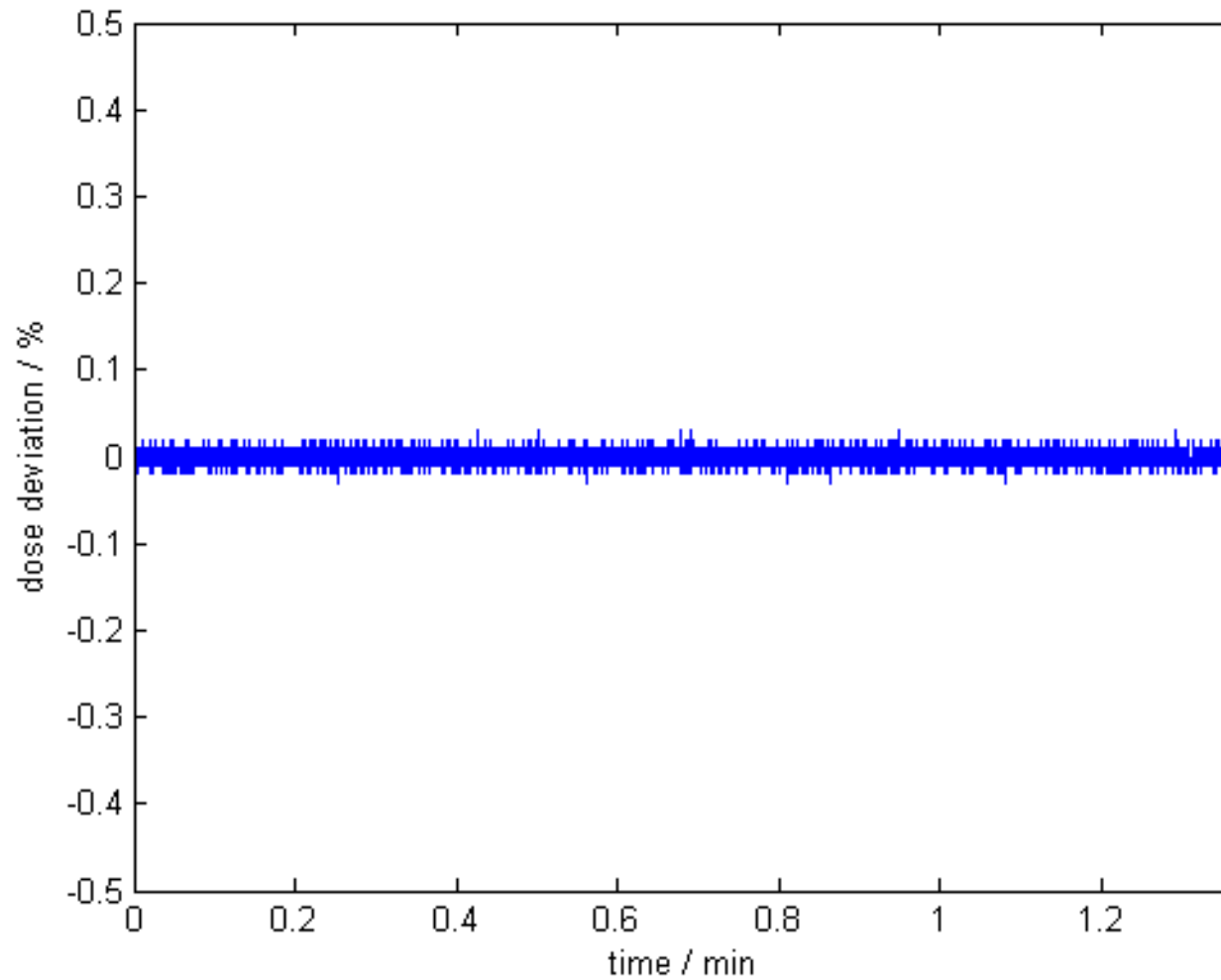
U2 & U4 @ ASML

- Ushio 2 & Ushio 4 light sources (3100) are integrated to NXE:3300B to support scanner development
- U2 (20 kW configuration) & U4 (50 kW configuration) are being upgraded as well
- U2 has now printed its first wafer



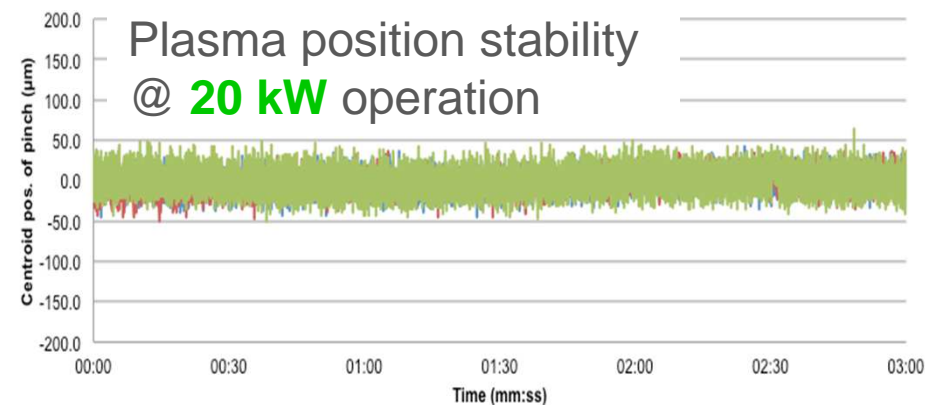
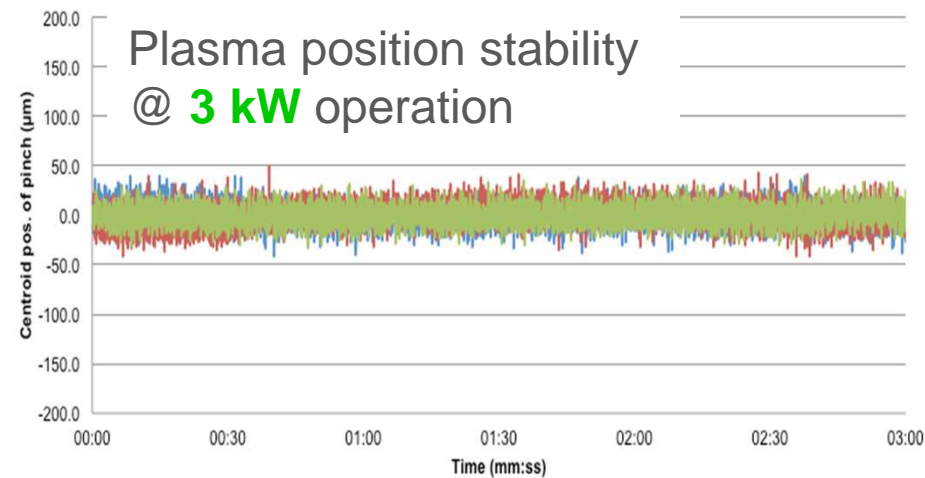
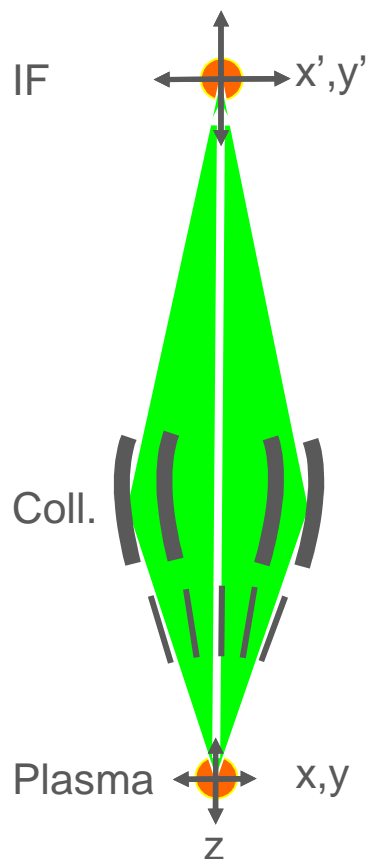
LDP Dose Stability at 20kW

- Dose stability is $3\sigma < 0.1\%$
 - Specification: $3\sigma < 0.2\%$



LDP Stability = Plasma Position Stability

- Laser focus, Tin and plasma are always at the surface of the wheel
- Plasma position remains stable with power scaling



→ Stable laser focus

→ Stable plasma position

→ Stable Far Field image

→ No dose variation caused by plasma position instability

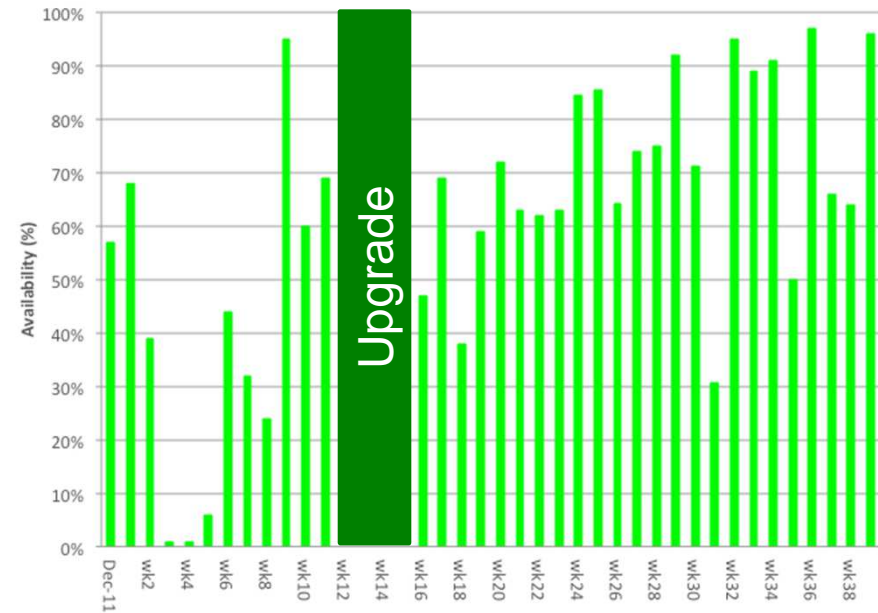
XTREME's 2012 Objectives

- To drastically improve and stabilize the reliability of XT's 3100 source at IMEC to enable Affiliate Chipmakers to develop their EUV process

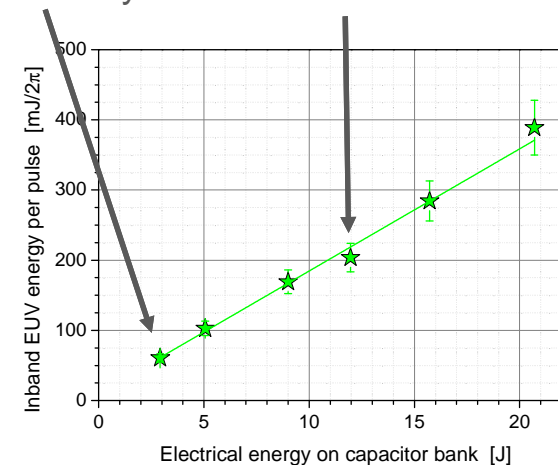
☑ Done

- To prove LDP long term scalability

☑ Done



~ IMEC Today ~ NXE:3300 B >> NXE:3300 B



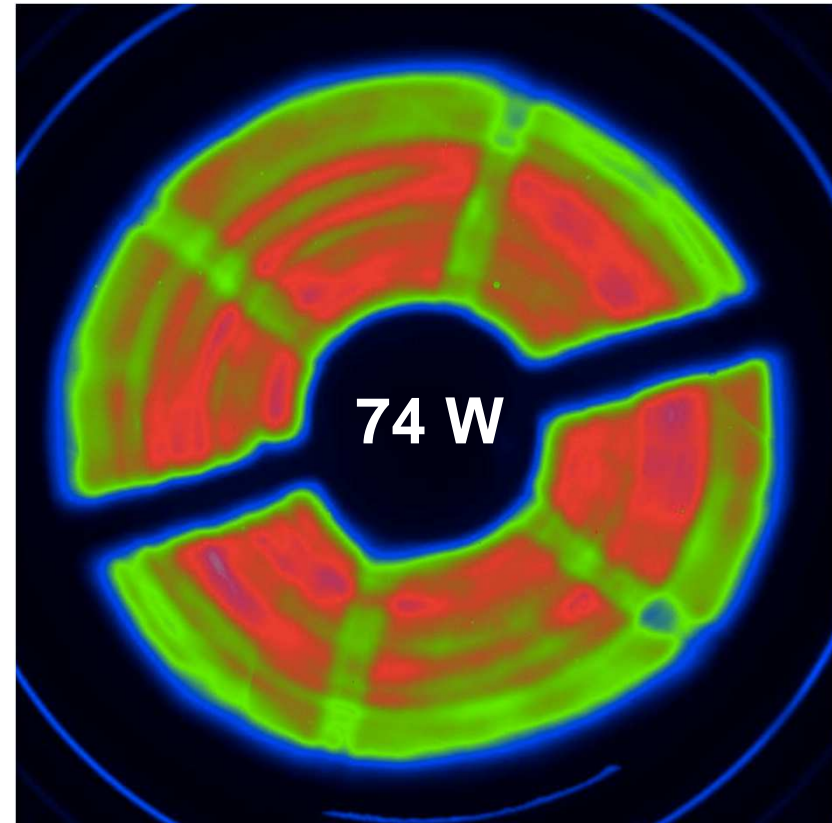
XTREME's 2012 Objectives

- To resume power scaling and demonstrate 50W

☑ Done

- To upgrade XT's 3100 source at IMEC for higher power

☐ Soon



Conclusions

- EUV is **a reality in the making** supported by recent progresses of LDP
- **No more claims. Results are in:**
 - LDP is scalable in the long term
 - **74W power after IF** was demonstrated on an integrated source
 - LDP technology is now being turned into a viable product and **high uptime** is achieved
- The night is always darker before dawn ... but the **EUV revolution is around the corner**

The logo for USHIO GROUP is displayed in white text on a dark green background. The word "USHIO" is in a large, bold, sans-serif font, and the word "GROUP" is in a smaller, all-caps, sans-serif font directly below it.

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Acknowledgments

- XTREME would like to acknowledge this work has been possible thanks to a very valuable and fruitful collaboration with Fraunhofer ILT
- XTREME would also like to thank NEDO for their continued support

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THANK YOU VERY MUCH FOR YOUR ATTENTION



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